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SYNTHETIC TERRAIN IMAGERY
FOR HELMET-MOUNTED DISPLAY, VOLUME 3
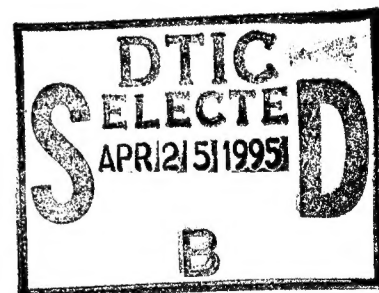
SOFTWARE USER'S MANUAL

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NOTICE

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13. ABSTRACT (Maximum 200 words)

The purpose of this document is to describe how to use the STI software program (STI). The software samples data from a preprocessed database created from the U.S. Defense Mapping Agency's Digital Terrain Elevation Data (DTED) database and renders, in perspective view, the visual scene. An NTSC video signal drives a helmet-mounted display. The Synthetic Terrain Imagery for Helmet Mounted Display program was written to present digital terrain elevation data to pilots in several different formats on an HMD. The program can be run standalone, in which case it behaves like the "flight" program that is provided by Silicon Graphics, or it can be integrated into a simulation environment wich communicates over the ethernet.

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Table of Contents

1.0   SCOPE

1.1   Identification

The software that has been developed as part of the <u>Synthetic Terrain Imagery for Helmet-Mounted Display</u> program is written in C and is designed to execute on a Silicon Graphics Workstation. This software was developed for purposes of evaluating the utility of synthetically derived representations of the local terrain presented on a helmet-mounted display.

1.2   System Overview

The software samples data from a preprocessed database created from the U.S. Defense Mapping Agency's Digital Terrain Elevation Data (DTED) database and renders, in perspective view, the visual scene. An NTSC video signal drives a helmet-mounted display. The Synthetic Terrain Imagery for Helmet Mounted Display program was written to present digital terrain elevation data to pilots in several different formats on an HMD. The program can be run standalone, in which case it behaves like the "flight" program that is provided by Silicon Graphics, or it can be integrated into a simulation environment which communicates over the ethernet.

1.3   Document Overview

The purpose of this document is to describe how to use the STI software program (STI).

This document is organized in accordance with Data Information specification DI-MCCR-80019A/T.

2.0   REFERENCED DOCUMENTS

There are no additional documents required for understanding the excutable code developed for the Sythetic Terrain Imagery for Helmet-Mounted Display computer program.

The interested reader is directed to two other documents developed under this program for additional background:

(1.)   Software Design Document, Contract No. F33615-92-C-3601, CDRL No. A002.

(2.)   Final Report, Contract No. F33615-92-C-3601, CDRL No. A001.

3.0   EXECUTION PROCEDURES

3.1   Initialization

To run the program type the following on the command line of an active window:

% sti {-ns} terrain.dma

The options can be exercised by adding the following to the command line:

-n sets the video output of the computer to RS-170A video format
-s displays the terrain in a RS-170A sized window on the high resolution
workstation monitor

note:
the terrain file is needed only when compiled standalone.

3.2 User Inputs

The following allows the user to modify the Synthetic Terrain Imagery in real-time.

OPERATOR KEY COMMANDS:

ESC KEY:	exit
F1 KEY:	set format to point post tops
F2 KEY:	set format to polygonal post tops
F3 KEY:	set format to wireframe mesh
F4 KEY:	set format to wireframe mesh with polygonal posts in the center of the mesh
F5 KEY:	set format to emergent detail, grid > 2000, grid plus points > 750 && < 2000, grid plus square posts < 750
F6 KEY:	set format to emergent detail, points > 2000, grid > 750 && < 2000, grid plus square posts < 750
F7 KEY:	set format to Optical Expansion Gradient
F8 KEY:	set format to Lighted Polygons
F9 KEY:	set format to Elevation shaded Polygons
F10 KEY:	set format to GD's orthogonal format
F11 KEY:	set format to ridgelines + post tops
F12 KEY:	set format to ridgelines + gradient
I/O KEY:	increase/decrease the spacing between posts. spacing can take on the values of 100, 200, 400 or 800 meters.
UP/DOWN ARROW:	increase/decrease the side length of the polygonal posts
C KEY:	toggle depth cueing
Q KEY:	toggle single or double width lines
H KEY:	toggle hidden point/line removal
M/L KEY:	increase/decrease the distance to local horizon
B/D KEY:	brighten/darken the STI
T KEY:	toggle display of terrain on/off
V KEY:	toggle variable local horizon on/off

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The following key commands are for STANDALONE operation only:

S/A KEY:	increase/decrease velocity
HOME KEY:	return simulation to original position
L/RT MOUSE:	slew the helmet
MIDDLE MOUSE:	reset helmet to 0
MOUSE POSITION:	
MOUSE-X:	roll of the plane
MOUSE-Y:	pitch of the plane
	to turn, roll the plane about 90 degrees, and then pull back on the mouse.

3.3 System Inputs

The software accepts input from an aircraft simulation (either Silicon Graphics' Flight Simulator or a high fidelity aero simulation through an Ethernet connection).

3.3.1 Inputs

The STI program can be compiled for networked operation, where it gets all inputs from other simulations, or it can be compiled for standalone operation by including the -DSTANDALONE flag on the compile line in the makefile.

3.3.1.1 Networked

When compiled normally the STI program accesses terrain data in global memory that has been loaded by another program. The STI program opens the terrain data and gets a pointer the global data structure in the routine attach_tdb which is defined in the file dma.c and called by the main program sti.c.

The position and other data for own-ship is also pulled out of global memory. (Actually the data comes in over the Ethernet and is put into global memory by another program. From the STI point of view the data comes from global memory.) The own-ship data is pulled from global memory and processed by the routine control.c. At this point the own-ship location coordinates are converted from degrees to feet.

3.3.1.1 Standalone

When the -DSTANDALONE flag is included on the compile line in the STI makefile, the program is compiled to run self contained without any other programs running. In this situation the path to a terrain data file must be passed as a parameter on the command line. Own-ship data is calculated internally and the keyboard user interface is active allowing the user to control the own-ship with the mouse and keyboard.

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3.3.2 Input/Output Data Elements

The data inputs to the STI simulation are specified in the targets.h and terrain.h include files. This information is copied from global memory during each iteration within control.c. Additional data is computed by the routine Angle_computations called within control.c

Information specific to the terrain data is described in the include file terrain_db.h written by Lockheed. This information is pulled from global memory and put into local variables by the routine fillglobals called from sti.c.

STI Global Variables

float SWLATITUDE;	/* Latitude of SW corner of database (in degrees) */
float SWLONGITUDE;	/* Longitude of SW corner of database (in degrees) */
int LATRES;	/* Number of points per degree Latitude */
int LNGRES;	/* Number of points per degree Longitude */
double LAT0;	/* Latitude of SW corner of database (in feet) */
double LNG0;	/* Longitude of SW corner of database (in feet) */
int xb;	/* beginning x extent of tile to be drawn index into elev. array*/
int xe;	/* ending x extent of tile to be drawn */
int yb;	/* beginning y extent of tile to be drawn */
int ye;	/* ending y extent of tile to be drawn */
int hidden;	/* hidden point/line removal on/off */
int skip;	/* distance (in posts) between displayed posts */
int depth;	/* depth-cueing on/off */
int fat;	/* lines are fat/skinny */
float position[4];	/* ownship position, x, y, z, x-east, y-north, z-up (in feet)*/
float heading;	/* compass heading of ownship */
float dist;	/* distance we can see (in feet) */
float aspect;	/* aspect ratio (x/y) of the display */
float fov;	/* field of view in the y direction (degrees)*/
float reclen;	/* length of the side of polygonal posts (feet)*/
FILE *dmafp;	/* file pointer to the terrain file */
Tile_t tiles[2];	/* elevation as it is read from disk */
Tile_t *tile;	/* pointer to the current buffer of tiles */

/*The field of view of helmet in x and y for displaying symbology*/

float hmd_fov_x1, hmd_fov_y1, hmd_fov_x2, hmd_fov_y2;

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```
/* declaration of the point arrays for the orthogonal and
        ridgeline algs. */
float h[2][5][300][3], vr[2][4][300][3], vl[2][4][300][3];
/* the number of points in each of the above arrays. */
int nph[2][5], npvr[2][4], npvl[2][4];

/* use a double buffered system for the DMA grids. While [toggle]
        is being set up, [!toggle] is being drawn. */
int toggle;
int format;

/* index which points to the current buffer being manipulated
        by concurrent processes. */
int mpbuf;

struct target_type os;        /* ownship data structure */
FILE *tfile;                  /* output timing file */
long fgmode;                  /* the fog mode currently being used */
float fgparms[5];             /* parameters for the fogvertex call */

Formal parameters (see appendix A for parameters to subroutines)
```

3.4 Termination

The program is terminated by hitting the ESC Key on the Silicon Graphics keyboard.

3.5 Restart

The program is restarted in the same manner as an "original" start, type the following:

% sti {-ns} terrain.dma'

3.6 Outputs

The STI program will currently render the terrain in any one of the following formats (subroutines to render the formats in parenthesis):

<u>Post tops</u>. In this format the terrain is rendered by drawing a point at the top of each post which is in the view volume.
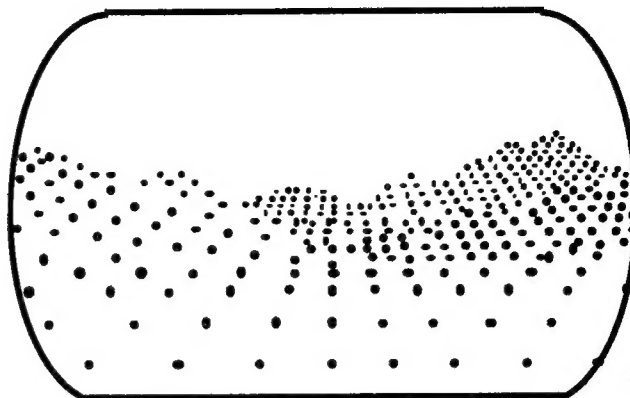
C920574-0

Post tops

<u>Square post tops (Tiles)</u>. This format will draw a square of variable size, as prescribed by the global variable reclen, at the top of each post within the view volume. The elevation data is bilinearly interpolated to obtain the z-value for each corner of the square, so the slope of the square is oriented to the terrain.

C920574-0

Tiles

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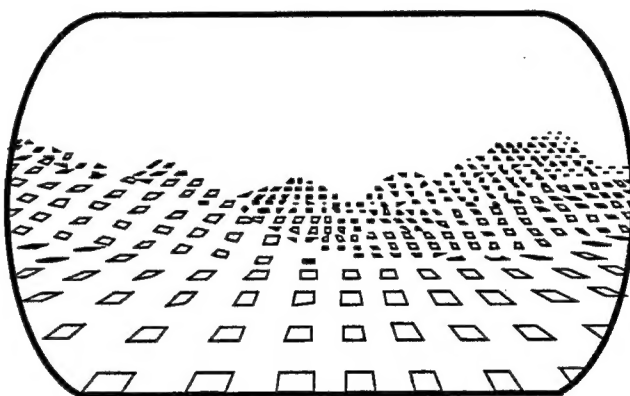
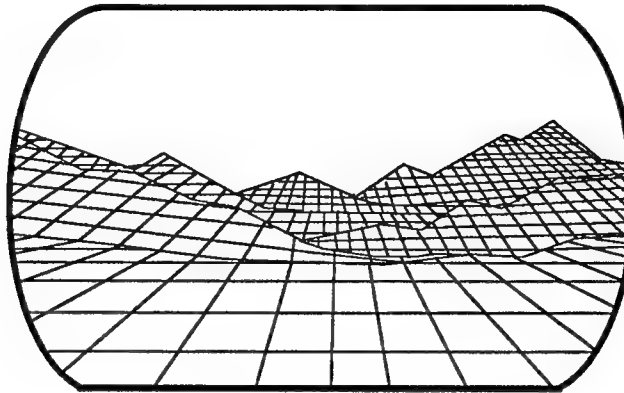Wireframe mesh. This format is rendered as a set of grids which are fixed to the terrain. It takes two passes through the elevation data to render the mesh. On the first pass, it draws all lines running east-west, and the second pass draws the lines running north-south.

C920574-0

Wireframe Mesh

Hybrid mesh and tiles. A wireframe mesh (see above) is first drawn, and then tiles are drawn in the center of the squares formed by the mesh. The tiles are drawn by the same routine which draws the square post tops (see above), but instead of putting the tiles at the post tops, they are offset to fill the gaps formed by the mesh.
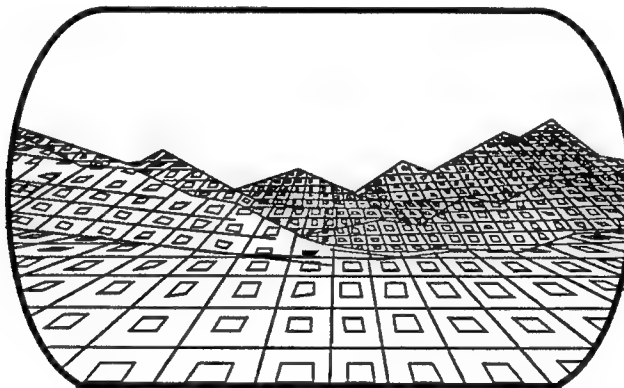
C920574-0

Hybrid Mesh and Tiles

Emergent detail #1. The emergent detail formats are an attempt to provide more detail as the pilot approaches the ground. When the height above ground level (AGL) is greater than 2000 feet, a wireframe mesh is drawn. When AGL is between 750 feet and 2000 feet a variant of the hybrid mentioned above is used with points instead of squares in the gaps formed by the mesh. When AGL is below 750 feet, the hybrid format is drawn.

Emergent detail #2. Above 2000 feet agl, Post tops are rendered. Between 750 and 2000, the mesh is drawn. Below 750 feet, the hybrid is drawn.

Optical expansion gradient. In this format, the terrain is rendered as lines running parallel to the motion of the plane. The gradient is fixed to the plane, so the elevation data must be bilinearly interpolated to find points along each line that is to be drawn.
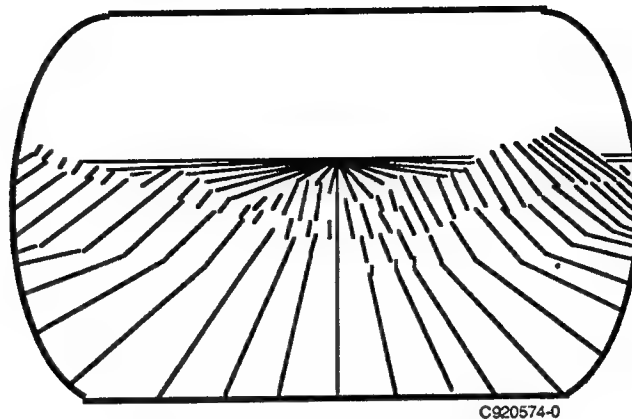
C920574-0

Optical Expansion Gradient

Lighted polygons. The terrain is rendered as lighted shaded polygons using the lighting utilities of the Silicon Graphics' graphics library. The color shading scheme goes from blue in the low regions to green in the middle regions to red in the upper regions. This is the only format that uses the surface normals of the elevation posts. A representation of this format is not shown in this document because of the reliance on color for meaningful perception of depth to occur.

Shaded polygons. This format displays the terrain as Gouraud shaded polygons. There is no lighting used. See the Description for Lighted polygons for the color scheme. A representation of this format is not shown in this document because of the reliance on color for meaningful perception of depth to occur.

Orthogonal format. In this head referenced format, ridgelines are drawn at 1.5, 3.0, 4.5 and 6.0 NM intervals. Four angular projection lines are then drawn at $\pm 20^\circ$ from the line of sight of the HMD. To facilitate drawing time, one set of point arrays is drawn while a second set is being updated.
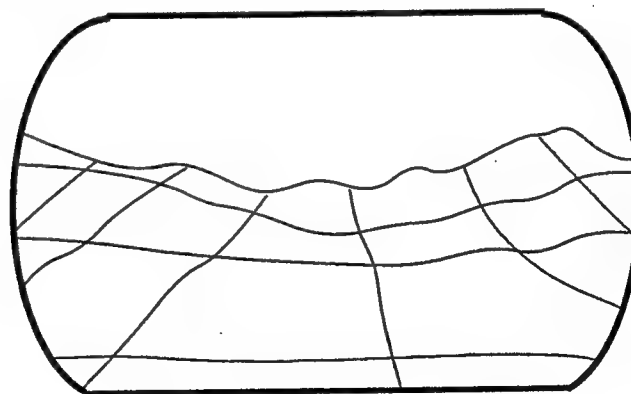
BC-HMD-GD-TO1

Orthogonal Format

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Ridgelines and post tops. This format renders the terrain as ridgelines plus the post top format to add detail.
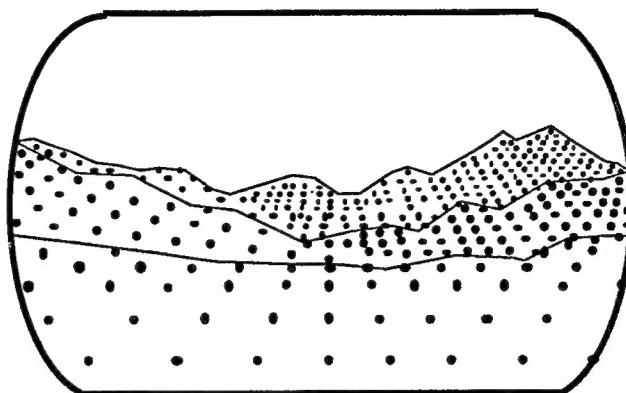
BC-HMD-02

Ridgelines with Posttops

Ridgelines and gradient. This format is similar to the orthogonal format. It draws ridgelines with the optical expansion gradient. The difference between this and the orthogonal format is that the spacing may be varied between the gradient lines by changing the global variable skip, while the orthogonal format always has a fixed spacing.
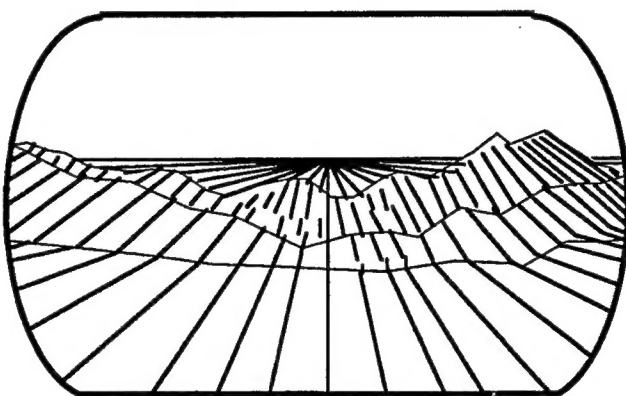
BC-HMD-03

Ridgelines and Gradient

4.0   ERROR MESSAGES

In the main function, if there are any errors opening the ethernet connection, opening the terrain file, or if the processes could not be spawned, the program will exit gracefully and return to the shell. In the loadtile function, the process will exit if a block of memory could not be allocated or read. The getelev function checks for several errors. If the Tile_t structures *tile does not point to relevant data, the function returns 0.0, and if the x,y coordinates are not contained in the current tile in memory, out of bounds array indices will be detected, and 0.0 is returned.

5.0   NOTES – DATA CONVERSION

The format DMA data is a 32 Mbyte file containing elevations covering about a 3.5 x 3.5 degree area of the world. A utility, Convert_DMA_to_GD_format.c is provided to convert 16 standard DMA elevation files into this format. The files to be converted are listed in "file_list" a separate file. The order is very important, and is described fully in

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the routine. If you are missing a file needed for an area (not all areas exist), the word "zeroit" may be used to define a 1x1 degree area of elevation zero. (see the Convert_DMA_to_GD_format.c file for further information).

Appendix A
Quickstart

The following is provided to enable the user to execute the Synthetic Terrain Imagery software with a minimum amount of documentation. For further detail it is recommended that the remainder of the manual be scanned for specific issues.

PROGRAM EXECUTION:

to run:

% sti {-ens} terrain.dma

options:
-e enables GD's ethernet protocol. Don't need to supply a file name with this option because a filename is asked for over the ethernet.
-n sets the video output of the computer to RS-170A video format
-s displays the terrain in a RS-170A sized window on the high resolution workstation monitor

note:
the terrain file is needed in all cases except when using the ethernet.

OPERATOR KEY COMMANDS:

ESC KEY:	exit
F1 KEY:	set format to point post tops
F2 KEY:	set format to polygonal post tops
F3 KEY:	set format to wireframe mesh
F4 KEY:	set format to wireframe mesh with polygonal posts in the center of the mesh
F5 KEY:	set format to emergent detail, grid > 2000, grid plus points > 750 && < 2000, grid plus square posts < 750
F6 KEY:	set format to emergent detail, points > 2000, grid > 750 && < 2000, grid plus square posts < 750
F7 KEY:	set format to Optical Expansion Gradient
F8 KEY:	set format to Lighted Polygons
F9 KEY:	set format to Elevation shaded Polygons
F10 KEY:	set format to GD's orthogonal format
F11 KEY:	set format to ridgelines + post tops
F12 KEY:	set format to ridgelines + gradient
I/O KEY:	increase/decrease the spacing between posts. spacing can take on the values of 100, 200, 400 or 800 meters.
UP/DOWN ARROW:	increase/decrease the side length of the polygonal posts
C KEY:	toggle depth cueing
Q KEY:	toggle single or double width lines
H KEY:	toggle hidden point/line removal
M/L KEY:	increase/decrease the distance to local horizon
B/D KEY:	brighten/darken the STI
T KEY:	toggle display of terrain on/off

V KEY: toggle variable local horizon on/off

The following key commands are for STANDALONE operation only:

S/A KEY:	increase/decrease velocity
HOME KEY:	return simulation to original position
L/RT MOUSE:	slew the helmet
MIDDLE MOUSE:	reset helmet to 0

MOUSE POSITION:

MOUSE-X:	roll of the plane
MOUSE-Y:	pitch of the plane
	to turn, roll the plane about 90 degrees, and then pull back on the mouse.

TERRAIN DATA FILE CONVERSION:

The source for the conversion from DMA's DTED format to GD's format is provided in the file Convert_DMA_to_GD_format.c. This command will have to be compiled. See the source for directions on how to use the tool.